DEVELOPMENT OF A NEW AIRBORNE HYPERSPECTRAL IMAGER FOR VOLCANO OBSERVATIONS

Tetsuya Jitsufuchi

National Research Institute for Earth Science and Disaster Prevention
jitu@bosai.go.jp
Tennodai 3-1, TSUKUBA, IBARAKI, JAPAN 305-0006

1. INTRODUCTION

There are 108 active volcanoes in Japan and about 1,500 worldwide. To reduce the damage caused by these volcanoes, we are developing technologies to mitigate volcanic disasters. One such technique utilizes airborne imaging for spectral remote sensing. Airborne imaging spectral systems can often efficiently identify volcanic phenomena that are difficult or impossible to detect by satellite imagery, aerial photography, or even ground surveys [1], [2]. Since 1990, the National Research Institute for Earth Science and Disaster Prevention (NIED) has been developing original airborne imaging spectral systems for mapping geothermal distributions, ash-fall areas, and volcanic gas columnar content. Our first system was VAM-90A, a scanning spectrometer with nine spectral bands developed by NIED in 1990. By 2005, VAM-90A had acquired about 190 images of volcanoes [3]. After developing VAM-90A, we developed a new airborne hyperspectral sensor, the Airborne Radiative Transfer Spectral Scanner (ARTS), in March 2006. ARTS is an alternative to VAM-90A and began operational volcano observation in 2008.

In this study, we describe the ARTS system specifications and present some in-flight performance test results obtained from the ARTS instrument overflight of the NIED building site on April 5, 2007, and the volcano observation flight over an active volcano (Sakurajima volcano) just after its eruption on April 8, 2008. At the NIED building site, we validated the radiometric fidelity of all bands and the accuracy of geo-corrections. At the Sakurajima volcano, we tried to demonstrate the functions of ARTS, especially those for volcano observation.

2. ARTS SYSTEM SPECIFICATIONS

ARTS is a push-broom imaging spectrometer covering wavelengths from 380 to 2450nm and 8000 to 11500nm with 421 bands. The ARTS imaging spectrometer consists of three sensor head units (SHUs). These SHUs are the visible-near infrared (VNIR) SHU, the shortwave infrared (SWIR) SHU, and the long-wave infrared (LWIR) SHU. These sensor head units operate from an aircraft as a line scanner in the push-broom mode. The VNIR SHU covers wavelengths from 380 to 1050nm with 288 spectrum bands. The field of view (FOV) is 40 degrees, and the image of this SHU is 1500 pixels wide cross track, making the instantaneous field of view (IFOV) 0.49mrad. The SWIR SHU covers wavelengths from 900 to 2450nm with 101 spectrum bands. The LWIR SHU covers wavelengths from 8000 to 11500nm with 32 spectrum bands. SWIR SHU and LWIR SHU have FOVs of 40 degrees and 600-pixel-wide images cross track, giving them an IFOV of 1.2mrad. ARTS has precise position and attitude measurement systems (GPS/IMU). Direct, accurate geo-corrections of each SHU image can be made using the GPS/IMU systems.

3. IN-FLIGHT PERFORMANCE TEST

ARTS images were acquired over Tsukuba Science City including the NIED building site at 1048 (UTC+9) April 5, 2007. ARTS was flown on a clear day at 1,000m A.G.L. Tsukuba Science City is a flat area located about 60km northeast of Tokyo, Japan, at an elevation of about 25m. At the NIED building site, we validated the radiometric fidelity of all bands and the accuracy of geo-corrections. Field reflectance and temperature of three test targets (Tyvek, blue PE sheet, and a water pool) on the NIED main building roof were measured coincidentally using an Analytical Spectral Devices FieldSpec Pro (ASD) and an NEC-sanei TH7102/WX infrared thermal-imaging camera for ARTS radiometric data validation. Nominal distances (27.431m) between bases in NIED's baseball field were measured by rectified image data from ARTS VNIR SHU. The size of the large-scale (49 X 76m) rainfall simulator facility in NIED was measured by rectified image data from ARTS SWIR and LWIR SHUs.

3.1 Result of radiometric validation of ARTS

The percent difference of the radiance is typically 0.1 to 5% for VNIR (440 to 1020nm) and SWIR (950 to 2350nm) bands, and 0.1 to 2% for LWIR (8000 to 11500nm) bands, except for those bands strongly affected by the atmosphere (Fig. 1).

3.2 Result of validation for rectification accuracy

The measured distances from the VNIR image between bases in the diamond are 28.0m (home plate to first base), 27.0m (first base to second base), 28.0m (second base to third base), and 27.0m (third base to home plate). The size of the large-scale rainfall simulator facility is 49 X 76m as measured from the SWIR image and 48 X 77m as measured from the LWIR image. The measured distances from each image demonstrate accurate geo-corrections of each SHU image with less than a two-pixel difference among SHUs.

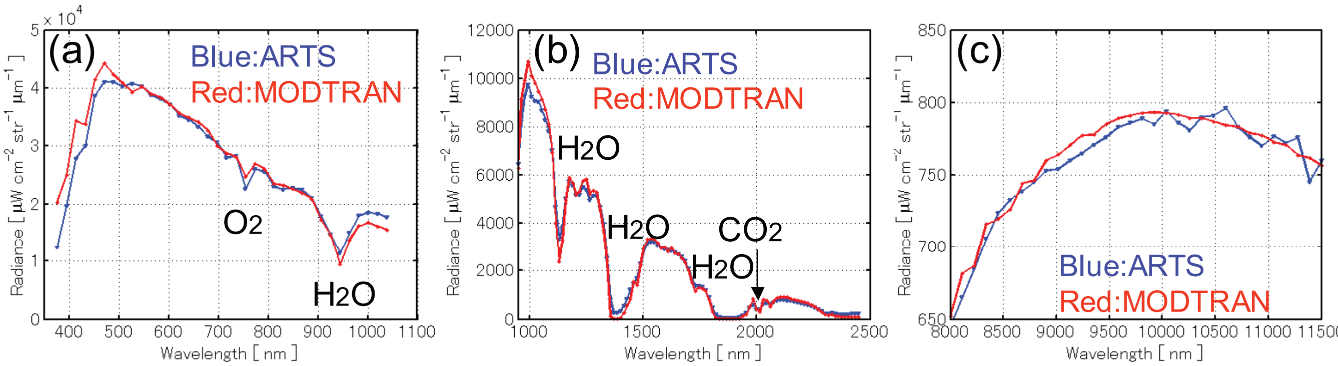

Fig. 1. ARTS radiance spectra from isolated test targets (blue) and the predicted band-averaged radiance from MODTRAN calculations (red). (a) VNIR radiance spectra from Tyvek. (b) SWIR radiance spectra from blue polyethylene. (c) LWIR radiance spectra from water pool.

4. HYPERSPECTRAL VOLCANO OBSERVATIONS

ARTS images were acquired over Sakurajima volcano at 1041 (UTC+9) April 8, 2008. ARTS was flown on a clear day at 4,000m A.S.L. Sakurajima volcano is located about 1200km southwest of Tokyo, Japan, at an elevation of about 1100m. At the Sakurajima volcano, the geo-corrected image was calculated directly using the data from the GPS/IMU system. This image can be superimposed onto a topographical map with sufficient accuracy for practical use. We could detect the geothermal activities of Sakurajima crater (Minamidake A-crater and Showa crater) (Fig. 2). The estimated maximum brightness temperature of Minamidake A-crater is 854 degrees C as measured from the radiance at 1001nm and 345 degrees C as measured from the radiance at 10260nm. The estimated maximum brightness temperature of Showa crater is 435 degrees C as measured from the radiance at 1625nm and 176 degrees C as measured from the radiance at 10260nm. These results indicate the existence of surface-temperature fields of subpixel resolution [4]. Under these conditions, the shorter wavelengths of ARTS estimate maximum temperature better than the longer wavelengths. These results demonstrate ARTS' ability to estimate temperature. In addition, the sulfur dioxide gas abundance inside the Minamidake A-crater area could be estimated from the LWIR data.

5. CONCLUSIONS

We developed a new airborne hyperspectral sensor, ARTS, for hyperspectral volcano observations and presented the results of two observations, the validation flight over NIED building and the volcano observation flight over an active volcano (Sakurajima volcano). The validation results indicate that the geo-correction accuracy is typically within two pixels (RMS) for each SHU, and that there was good agreement between the predicted radiance at the sensor and the measured radiance at the sensor at a flight altitude of 1000m A.G.L. The geothermal

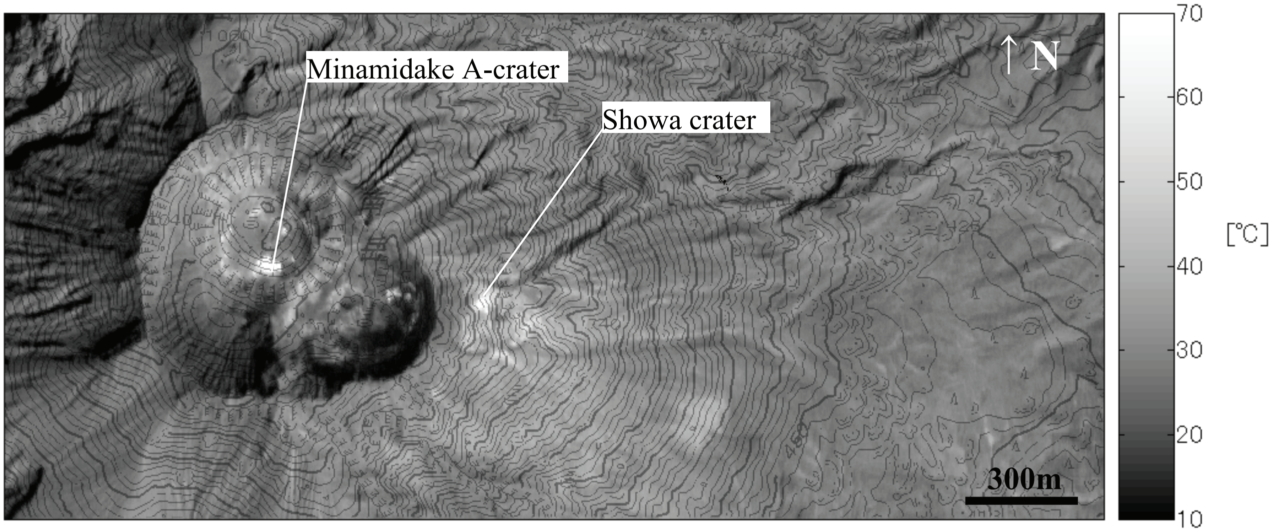

Fig. 2. Orthorectified ground-surface brightness-temperature image around the Minamidake A-crater and the Showa crater as measured from the radiance at 10260nm superimposed onto a topographical map.

activity can be estimated using VNIR, SWIR, and LWIR spectra from ARTS. The shorter wavelengths estimate maximum temperature better than the longer wavelengths when there are surface-temperature fields of subpixel resolution. The sulfur dioxide gas abundance could be estimated from the LWIR data. From these results, we conclude that ARTS is a well calibrated instrument for assessing volcanic activity.

11. REFERENCES

[1] R.G. Vaughan, S. J. Hook, M.S. Ramsey, V. J. Realmuto, and D. J. Schneider, "Monitoring eruptive activity at Mount St. Helens with TIR image, "*Geophys. Res. Lett.*., vol. 32, L19305, doi:10.1029/2005GL024112, 2005.

[2] V. Lombardo and M.F. Buongiorno, "Lava flow thermal analysis using three infrared bands of remote-sensing imagery: A study case from Mount Etna 2001 eruption," *Remote Sens. Environ.*., vol. 101, no.1, pp. 141-149, 2006.

[3] T. Jitsufuchi, M. Ukawa, E. Fujita, Y.Okada, S. Miyasaka, K. Akaike and S. Matsuoka, "Multitemporal observations of the 2000 Usu eruption using airborne multispectral scanners," *Bull. Volcanol. Soc. (Japan)*, vol. 47, no.4, pp. 297-323, 2002, in Japanese with English abstract.

[4] J. dozier, "A method for Satellite Identification of surface temperature fields of subpixel resolution" *Remote Sens. Environ.*, vol. 11, pp. 221-229, 1981.